LA-UR -83-3403

CONF-831106--9

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

LA-UR--83-3403

DE84 003848

TITLE: MATERIALS CONTROL AND ACCOUNTING (MC&A): THE EVOLUTIONARY PRESSURES

AUTHOR(S): J. P. Shipley

SUBMITTED TO: ANS/INMM Conference on Safeguards Technology: The Process-Safeguards Interface
Hilton Head Island, South Carolina
November 28, December 2, 1983

MATERIALS CONTROL AND ACCOUNTING (MC&A):

THE EVOLUTIONARY PRESSURES[a]

James P. Shipley, Los Alamos National Laboratory
Los Alamos, NM 87545
(505) 667-6394

ABSTRACT

Nuclear materials control and accounting systems are subject to pressures of both regulatory and institutional natures. This fact, coupled with the emergence of new technology, is causing evolutionary changes in materials control and accounting systems. These changes are the subject of this paper.

I. INTRODUCTION

Nuclear materials control and accounting systems continue to evolve in terms of both their fundamental philosophy and their typical implementations. The pressures driving this evolution arise from several sources, perhaps the largest two being regulatory and institutional concerns. At the same time, the enabling technology is emerging. That fact, together with a tighter coupling of process operating considerations and materials control and accounting, have important implications for the future. The purpose of this paper is to examine the combination of all these factors, supported by operating experience, with respect to directions of change.

II. REGULATORY PRESSURES

Various regulations or requirements arise under both domestic and international safeguards. In the domestic case, materials control and accounting requirements are laid out in Department of Energy (DOE) Order 5630 for DOE facilities. Nuclear Regulatory Commission (NRC) regulations govern commercial facilities, and the NRC has recently proposed a materials control and accounting reform amendment intended to upgrade those regulations. In the international case, requirements are promulgated by the International Atomic Energy Agency (IAEA) through its interactions with the Member States or by bilateral and multilateral agreements among various groups of countries.

In all of these cases the regulatory pressures are three pronged:

- more timely accounting,
- more sensitive accounting, and
- lower personnel radiation exposures necessary to achieve acceptable accounting quality.

In addition, the domestic scene is currently dominated by increasingly stringent threat guidance. Part of this threat guidance is intended to reinforce controls over those personnel normally having access to special nuclear material (SNM), thereby providing additional protection against threats that depend upon a knowledgeable insider. As a result, long-standing reliance on personnel integrity at the operating level is being questioned. The role of technology in alleviating the need for that reliance will become of increasing concern; that role is not likely to be one of decision making. Technology can best contribute by assuring that accurate and precise inputs are available to the decision maker, which will be a human for the foreseeable future.

The international safeguards problem is complicated by the emergence of new types of facilities to be safeguarded. These are the so-called bulk-handling facilities, of which enrichment, fuel fabrication, and reprocessing are the prime examples. The nature, number, and size of these facilities will demand a different approach to IAEA safeguards to address emerging performance requirements. The technology to satisfy these regulations and requirements in such facilities is still being developed.

In those cases where facilities are subject to both domestic and international safeguards requirements and regulations, it should be obvious that a substantial degree of compatibility between the two is highly desirable. This compatibility minimizes the redundancy and disruption that safeguards sometimes

[a]Work supported by the US Department of Energy, Office of Safeguards and Security.

imposes on a facility, which is both advantageous cost-wise and simpler for the facility operator.

III. INSTITUTIONAL PRESSURES

A second set of pressures neither directly opposed to nor in agreement with the regulatory ones comprises large-scale issues spanning questions of propriety, prerogatives, and perception. Those pressures include the following major ones:

- minimize the inappropriate release of proprietary, sensitive, and/or unnecessary information,
- optimize the impact of materials control and accounting on product quality,
- maximize safeguards effectiveness, especially as perceived by the outside, and
- minimize the cost of safeguards consistent with the above objectives.

This list is not exhaustive, but it certainly includes the major institutional factors. The last factor is especially important for international safeguards when considered in terms of manpower requirements. Manpower-intensive systems are not likely to be successful or acceptable in the long term.

It is important that safeguarders keep in mind just who it is that determines what the levels of these pressures are. Many individuals and entities play a role in that process, and almost none of them are solely safeguards oriented. Consequently, safeguards technologists can strive to relieve these pressures, but the determination of whether or not relief is sufficient is a collective one.

One of the pivotal issues concerning safeguards is that of performance evaluation. Again, we must keep in mind who does that evaluation, and there are four classes of evaluators: those who design, build, and operate the safeguards system; those who operate the facility that is safeguarded; those who depend on the safeguards system (the public, other countries, etc.); and those who would divert SNM. We can think of the four institutional pressures listed above as attributes in the performance evaluation of a safeguards system. These four attributes will be assigned, in either a formal or defacto way, different weights by each of the four evaluators. The task for a decision maker who would relieve these institutional pressures is to aggregate appropriately all these viewpoints.

IV. THE PROCESS/SAFEGUARDS COALITION

Several relevant facts help to alleviate such pressures and further the evolution of materials control and accounting systems in directions consistent with those pressures. First, safeguards technology has been emerging for several years in the way of improving both sensitivity and timeliness of materials control and accounting systems. For example, in-line, on-line, and at-line instrumentation is much more readily and widely available today. Supporting that instrumentation is the capability for logical safeguards systems design and integration, including, for example, techniques for quantitative performance analysis and statistical methods for evaluation of materials accounting data.

At the same time, the technology of process design, development, and control also is evolving. This means that many of the process design tools, which are an absolutely essential part of materials control and accounting systems design, can also be brought to bear for process engineering purposes. In addition, facility automation based on artificial intelligence and robotics is emerging as the wave of the future in process design and operation. This technology obviously will have substantial impacts on the nature and implementation of safeguards. For example, human exposure to the process environment will be minimized, resulting in both less radiation exposure and less potential for compromise of sensitive information.

It is by no means too soon to begin weaving all these threads together. The improved systems for tracking nuclear materials, which arise naturally from the improved safeguards technology developed for the evolving materials control and accounting systems, will provide benefits to the process operators. Modern systems will naturally build on current capabilities for process control in terms of available instrumentation and measurements that might be upgraded for materials control and accounting.

Examples of the results of these evolutionary pressures include the series of seven mini-run experiments at the Allied General

Nuclear Services Reprocessing Plant in Barnwell, South Carolina, the design of the Fuels Materials Examination Facility at Richland, Washington, and the design of the New Special Recovery Line at Savannah River. In each of these cases, the evolutionary pressures described above have been overriding factors. In every case these factors have been alleviated by a strong coalition of process and safeguards concerns. Such coalitions are absolutely necessary to achieve both maximum efficiency and effectiveness.

Perhaps the most outstanding example of the potential for mutual benefits to safeguards and the process is in the gas centrifuge enrichment plant (GCEP) now under construction at Portsmouth, Ohio. The usual IAEA inspection approach would call for an attributes and variables sample plan on 14-ton cylinders of UF_6 feed, product, and tails materials, necessitating inspector presence to carry out, for example, an attributes check on a substantial number of such cylinders. On the other hand, by providing a set of automated in-line enrichment monitors (EMs), the attributes checks on all cylinders would be automatically performed without the need for inspectors to be present, which would save several inspector man months for a two-building GCEP, which is the current plan. In addition, the GCEP operators would have to contribute perhaps three times that amount of their own resources to assist the IAEA if the EMs were not in place. The GCEP operator also benefits from having a continuous on-line measurement of the enrichment of material going into the product cylinders, a measurement that is highly desirable from a process operating standpoint. Even further, the EMs would provide substantially improved timeliness and sensitivity over the usual approach practiced by the IAEA. This is a case where every single performance measure is improved by advanced technology. It is the prototypic win-win situation.

V. POTENTIAL MATERIALS CONTROL AND ACCOUNTING

The potential for improvements in MC&A, as well as the limiting factors, may be seen by examining the structure of the materials balance and CUSUM uncertainties for a simple case. Consider a process having a series of inventory measurements $\{\bar{I}(k),\ k = 0, \ldots, N\}$, each given by

$$\bar{I}(k) = I(k)\,[1 + \epsilon_I(k) + \eta_I] \quad ,$$

where $I(k)$ is the true value, $\epsilon_I(k)$ is the uncorrelated, or random, inventory measurement error, and η_I is the correlated, sometimes called the systematic, inventory measurement error. We assume that both $\epsilon_I(k)$ and η_I come from stationary random processes, so that η_I is an unknown constant. Note that $\epsilon_I(k)$ and η_I are relative errors.

Similarly, let the set of net transfer measurements, $\{\bar{T}(k),\ k = 1, 2, \ldots, N\}$, each be given by

$$\bar{T}(k) = T(k) + \epsilon_T(k) + \eta_T \quad ,$$

with similar restrictions and definitions as before. The variances of the four random variables, $\epsilon_I(k)$, η_I, $\epsilon_T(k)$, η_T, are constant and given, respectively, by

$$\sigma^2_{\epsilon I} \quad \sigma^2_{\eta I} \quad \sigma^2_{\epsilon T} \quad \sigma^2_{\eta T} \quad .$$

It is straightforward to show that the variance of the CUSUM over N balances, which is the same as a single materials balance over the N periods, can be written as

$$\sigma^2_{\epsilon}(N) = [I^2(0) + I^2(N)]\sigma^2_{\epsilon I} + [I(0) - I(N)]^2\sigma^2_{\eta I} + N\sigma^2_{\epsilon T} + N^2\sigma^2_{\eta T} \quad ,$$

if η_I and η_T are constant. We can use this equation to make the following observations.

In high-throughput processes, the relative accuracy between feed and product measurements limits the long-term detection sensitivity, and long-term relative biases between feed and product measurements should be controlled. Theoretically, the limiting factor is the uncertainty in the relative bias between the physical standards used for these measurements, which may be <0.1%. Consequently, it is difficult to imagine a long-term detection sensitivity better than about 0.1% of the throughput.

In contrast, the precision of the in-process inventory measurements and the variability of any unmeasured holdup are the limiting uncertainties in short-term detection.

Even with very precise measurements, large buffer-storage tanks may introduce large absolute errors that will seriously degrade the short-term detection sensitivity. On the other hand, relatively minor holdups and sidestreams will have little effect on detection sensitivity, and estimates based on historical data can be used until these components are measured, for example, during a physical inventory. On the basis of past operating experience, I believe that 1% of the inventory is a reasonable limit to the short-term detection sensitivity.

What can be done about these limitations? The nature of the problem suggests the following three-point approach:

- Create materials balances that are sufficiently small in time and space so that detection sensitivities are suitable.

- Postulate that any diversion threat is limited to a very few locations, with minimal opportunity for successful tampering or falsification.

- Construct a set of administrative procedures, augmented by security technology, to ensure that the above situation holds.

This approach, coupled with recognition of the structure and potential of MC&A systems, has profound implications for the future directions of MC&A evolution.

VI. CONCLUSIONS

The most difficult aspect of improving the safeguards situation, be it domestic or international, civilian or military, is to convince people that advancing safeguards technology may not be just a burden, but may have benevolent, beneficial consequences. Very often we can be in that happy situation where cost and effectiveness don't have to be traded off against one another. Both may improve simultaneously if we can get ourselves to peer over the edge of the rut of tradition.

The evolutionary pressures described above, of course, cause evolutionary trends in the technology of materials control and accounting. These trends affect both the devices of materials accounting and the systems of materials accounting. I characterize them as follows:

- Instrumentation
  - smart, easy to use
  - remote operation, tamper safe
  - networkable
  - reliable, robust
  - well-characterized

- Systems
  - close-coupled materials accounting
  - more timely, sensitive materials accounting
  - well-characterized
  - computer-based inspection systems
  - statistical pattern recognition for diversion detection
  - resource allocation optimization.

I believe these trends are inevitable and necessary. Like any growth, they will not come without pain and uncertainty, but the alternatives are not acceptable. In actuality our outlook should be much more positive. Encouragement of the trends outlined here just may have substantial benefits for all of us. It's a possibility worth investigating.